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For: A METHOD AND ASSOCIATED DEVICE FOR FILTERING DIGITAL VIDEO IMAGES

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Keksinnön nimitys
Title of invention

"A method for filtering digital video images"
(Menetelmä digitaalisten videokuvien suodattamiseksi)

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A method for filtering digital video images

The present invention relates to a method for removing blocking artefacts from a frame of a digital video signal, which has been coded by blocks and then decoded, the coding method for a block being selected according to a predetermined set of coding types, in which method at least one pixel is selected for examination from at least one side of a block boundary, and a value of at least one pixel selected for examination is corrected by filtering. The present invention relates also to a device for removing blocking artefacts from a frame of a digital video signal, which has been coded by blocks and then decoded, the coding method for a block being selected according to a predetermined set of coding types, which device comprises means for selecting at least one pixel for examination from at least one side of a block boundary, and a filter for correcting a value of at least one pixel selected for examination. The present invention relates furthermore to a video encoder according to the preamble of Claim 22, a video decoder according to the preamble of Claim 24, a video codec according to the preamble of Claim 25, and a mobile terminal according to the preamble of Claim 26. The present invention relates furthermore to a storage media for storing a software program comprising machine executable steps for coding and decoding a digital video signal by blocks, for selecting the coding method for a block according to a predetermined set of coding types, for removing blocking artefacts from a frame of a digital video signal, for selecting at least one pixel for examination from at least one side of a block boundary, for correcting the value of pixels selected for examination by filtering.

A transmission system like the one shown in Figure 1 is generally used for transferring a digital video image in compressed form. The video image is formed of sequential frames. In some prior art video transmission systems, for example ITU-T H.261/H.263 recommendations, three frame types are defined: an I-frame (Intra), a P-frame (Predicted or Inter), and a B-frame (Bi-directional). The I-frame is generated solely on the basis of information contained in the image itself, wherein at the receiving end, this I-frame can be used to form the entire image. P-frames are formed on the basis of a preceding I-frame or P-frame, wherein at the receiving stage a preceding I-frame or P-frame is

correspondingly used together with the received P-frame in order to reconstruct the image. The preceding I-frame is also used as a reference frame as will be explained later in this description. In the composition of P-frames, for instance motion compensation is used to compress the quantity of information. B-frames are formed on the basis of the preceding P-frame or I-frame and/or the following P- or I-frame.

The frames are further divided into blocks. One or more such blocks forms a block region. There can generally be four different region types: Intra region, copy region, coded region, and not-coded region. An intra region is a block region in which the blocks are coded independently without reference to any other frame. A copy region consists of blocks which are obtained by copying the content of the reference frame into exactly the same location without any motion compensated prediction. A coded region consists of blocks which are obtained using motion compensated prediction and prediction error coding. The prediction error is a difference between the pixel values of the actual frame and a reconstructed frame which is formed by using coding and decoding in a transmitting system. The prediction error is then coded and sent to a receiver. A not-coded region is obtained using motion compensated prediction only. In fact the not-coded region is equivalent to a copy region if the motion information equals 0. All the block regions of one frame are not necessarily similar types but one frame can comprise block regions which are of different types.

A current video frame to be coded comes to the transmission system 10 as input data $I_n(x,y)$. In the differential summer 11 it is transformed into a prediction error frame $E_n(x,y)$ by subtracting from it a prediction frame $P_n(x,y)$ formed on the basis of previous images. The prediction error frame is coded in block 12 in a manner described hereinafter, and the coded prediction error frame is directed to a multiplexer 13. To form a new prediction frame, the coded prediction error frame is also directed to a decoder 14, which produces a decoded prediction error frame $\hat{E}_n(x,y)$ which is summed in a summer 15 with the prediction frame $P_n(x,y)$, resulting in a decoded frame $\hat{I}_n(x,y)$. The decoded frame is saved in a frame memory 16. To code the next frame, the frame saved in the frame memory 16 is read as a reference frame $R_n(x,y)$ and

in a motion compensation and prediction block 17 it is transformed into a new prediction frame according to the formula

$$P_n(x,y) = R_n[x + Dx(x,y), y + Dy(x,y)] \quad (1)$$

The pair of numbers [Dx(x,y), Dy(x,y)] is called the motion vector of the pixel at location (x,y) and the numbers Dx(x,y) and Dy(x,y) are the horizontal and vertical shifts of the pixel. They are calculated in a motion estimation block 18. The set of motion vectors [Dx(·), Dy(·)] consisting of all motion vectors related to the pixels of the frame to be compressed is also coded using a motion model comprising basis functions and coefficients. The coefficient values are coded and directed to the multiplexer 13, which multiplexes them into the same data stream with a coded prediction error frame for sending to a receiver. In this way the amount of information to be transmitted is dramatically reduced. The basis functions are known to both the encoder and the decoder. Some frames can be partly or entirely so difficult to predict that it is not practical to use motion compensated prediction when coding them. These frames or parts of frames are coded using so-called intracoding without prediction, and therefore it is not necessary to send motion vector information relating to them to the receiver.

In the receiver system 20, a demultiplexer 21 separates the coded prediction error frames and the motion information transmitted by the motion vectors and directs the coded prediction error frames to a decoder 22, which produces a decoded prediction error frame $\hat{E}_n(x,y)$, which is summed in a summer 23 with the prediction frame $P_n(x,y)$ formed on the basis of a previous frame, resulting in a decoded frame $\hat{I}_n(x,y)$. The decoded frame is directed to an output 24 of the decoder and at the same time saved in a frame memory 25. When decoding the next frame, the frame saved in the frame memory is read as a reference frame and transformed into a new prediction frame in the motion compensation and prediction block 26, according to formula (1) presented above.

The coding method applied in block 12 to the coding of the prediction error frame or to the intracoding of a frame or part of a P-frame to be sent without prediction, is generally based on a transformation, the

most common of which is Discrete Cosine Transformation, DCT. The frame is divided into adjacent blocks sized e.g. 8 x 8 pixels. In coding and decoding, the blocks are processed independent of one another. The transformation is calculated for the block to be coded, resulting in a series of terms. The coefficients of these terms are quantized on a discrete scale in order that they can be processed digitally. Quantization causes rounding errors, which can become visible in an image reconstructed from blocks so that there is a discontinuity of pixel values at the boundary between two adjacent blocks. Because a certain decoded frame is used for calculating the prediction frame for the next frames, the errors can be propagated in sequential frames, thus causing visible edges in the image reproduced by the receiver. Image errors of this type are called blocking artefacts.

Some prior art methods are known for removing blocking artefacts. These methods are characterized by the following features:

- determining which pixel requires value correction in order to remove the blocking artefact,

- determining a suitable low-pass filtering for each pixel to be corrected, based on the values of other pixels contained by a filtering window placed around the pixel,

- calculating a new value for the pixel to be corrected, and

- rounding the new value to the closest digitized pixel value.

Factors that influence the selection of a filter and the decision to use filtering can be, for example, the difference between the values of pixels across the block boundary, the size of the quantization step of the coefficients received as the transformation result, and the difference of the pixel values on different sides of the pixel being processed.

It has been found that the prior art methods also tend to remove lines of the image that should really be part of it. On the other hand, the prior art methods are not always capable of removing all blocking artefacts.

The objective of the present invention is to present a new kind of filtering arrangement for removing blocking artefacts. The invention also has the objective that the method and device according to it operate more reliably and efficiently than prior art solutions.

The method according to the invention is intended to adjust filtering parameters according to the type of blocks whose boundary is to be filtered. Different filtering parameters are chosen according to the type of block on either side of the boundary in order to yield an improved filtering result.

The objectives of the invention are achieved by adapting the selection of pixels for filtering and the filtering process more flexibly than before to the features of the frame and the environment of the filtering point and by taking into account the nature/type of the blocks to be filtered.

The method according to the invention for removing blocking artefacts from a frame that has been coded by blocks, in which method at least one pixel from at least one side of the block boundary is selected for examination, is characterized in that the filtering applied on the block boundary depends on the block types of the frame in the environment of the block boundary.

The invention also relates to a device for implementing the method according to the invention. The device according to the invention is characterized in that the filter has been arranged to operate adaptively according to the block types of the frame in the environment of the block boundary.

The encoder according to the invention is characterized in that the filter has been arranged to operate adaptively according to the block types of the frame in the environment of the block boundary. The decoder according to the invention is characterized in that the filter has been arranged to operate adaptively according to the block types of the frame in the environment of the block boundary. The codec according to the invention is characterized in that the filter has been arranged to operate adaptively according to the block types of the frame in the environment of the block boundary. The mobile terminal according to the

invention is characterized in that the filter has been arranged to operate adaptively according to the block types of the frame in the environment of the block boundary. The storage media according to the invention is characterized in that the software program further comprises machine executable steps for filtering adaptively according to the block types of the frame in the environment of the block boundary.

Because blocking artefacts only occur at block boundaries, the filtering according to the invention is only applied to pixels at block boundaries and the immediate vicinity thereof. Edges that are part of the image can reside anywhere in the image area. In order that only pixels containing blocking artefacts are selected for corrective filtering and that the quality of edges that are part of the image is not affected during filtering, the following assumptions have been made in the study that resulted in the invention:

The changes in pixel values associated with edges that are part of the image, are generally larger than those associated with blocking artefacts, and those edges within the image, where the pixel value change is small do not suffer considerably from the rounding of the pixel value difference caused by filtering.

Because the image to be coded is generally divided into blocks both vertically and horizontally, the image contains both vertical and horizontal block boundaries. With regard to vertical block boundaries, there are pixels to the right and left of the boundary, and with regard to horizontal block boundaries, there are pixels above and below the boundary. In general, the location of the pixels can be described as being on a first or a second side of the block boundary. In the filtering method according to the invention, the number of pixels to be corrected, the characteristic features of the filter being used and the size of the filtering window depend on the following factors:

a) The type of block on either side of the boundary (inter, copy, coded, not-coded),

b) the difference in pixel values Δ across the block boundary (the difference can be defined in many ways; one definition is $\Delta = |r_1 -$

$l_1|$, where r_1 is the value of the pixel on the first side of the block boundary closest to the boundary, and l_1 is the value of the pixel on the second side of the block boundary closest to the boundary),

c) the size of the quantization step QP of the coefficients received as the result of the transformation used in coding, and

d) differences in pixel values between the pixels on the first side of the block boundary, and correspondingly between the pixels on the second side of the block boundary.

In the method and device according to the invention, the number of the pixels to be selected for filtering can vary, and it is not necessarily the same on different sides of the block boundary. The number of pixels also depends on the type of block on either side of the boundary. Because the number of pixels is adapted to the general features of the image information contained by the frame in a particular region according to the factors mentioned above, the method produces a better filtering result than that provided by prior art methods. A "better" result in this context is one in which blocking artefacts are reduced to a greater extent while real edges in the image are affected to a lesser degree.. A larger amount of blocking artefacts can be removed without weakening the real image edges unreasonably.

In the following, the invention will be described in more detail with reference to the preferred embodiments and the accompanying drawings, in which

Figure 1 represents a prior art video codec,

Figure 2 represents the location of pixels in relation to a block boundary in the method according to the invention,

Figure 3 represents alternatives for locating the filtering method according to the invention in a video codec,

Figure 4 is a schematic representation of a device for implementing a method according to the invention,

Figure 5 represents a device according to Figure 4 in operation, and

Figure 6 is a schematic representation of a portable teleconferencing device implementing a method according to the invention.

In the above, in connection with the description of the prior art, reference was made to Figure 1, and so in the following description of the invention and its preferred embodiments, reference will be made mostly to Figures 2 to 5. The same reference numbers are used for corresponding parts in the figures.

Figure 2 shows the location of the pixels r_1 - r_6 and l_1 - l_6 in relation to a vertical block boundary 30. To implement the method according to the invention, certain parameters must be specified. The parameter n is the largest number of pixels to be examined from the block boundary in one direction, and in the case of Figure 2 its value is 6. It is practical to select the value of the parameter n so that it has a certain relation to both the difference of the pixel values Δ across the block boundary and to the size of the quantization step QP of the coefficients received as the result of image coding. Furthermore, the value of the parameter n is advantageously smaller than or equal to the number of pixels in the block in the direction of examination to avoid possible blocking artefacts associated with previous block boundaries spreading to the block boundary under examination. The following definition is recommended for use in a preferred embodiment of the invention applied to image blocks comprising 8x8 pixels:

$$n = \begin{cases} 0 & \Delta \geq 2.00\alpha \\ 1 & 1.50\alpha \leq \Delta < 2.00\alpha \\ 2 & 1.00\alpha \leq \Delta < 1.50\alpha \\ 3 & 0.66\alpha \leq \Delta < 1.00\alpha \\ 4 & 0.40\alpha \leq \Delta < 0.66\alpha \\ 5 & 0.25\alpha \leq \Delta < 0.40\alpha \\ 6 & 0 \leq \Delta < 0.25\alpha \end{cases}, \qquad (2)$$

wherein $\alpha = QP \cdot \log(QP)$. If QP has a different value in blocks on different sides of the block boundary, the smaller value of QP is used in calculation, as well as in all cases presented hereinafter, in which a definition includes reference to one QP value only. The invention does not limit the determination of the value of parameter n, but according to the guidelines of the equation (2) it is advantageous that its value is generally higher when the difference of pixel values Δ across the block boundary is small in comparison to the size of the quantization step QP of the coefficients received as the result of the coding transformation. If the difference between the pixel values Δ is large, there is a high probability that there is a real image edge at the block boundary, and in this case the pixels are preferably not examined for filtering at all (n=0).

In the next step of the filtering method according to the invention region type information concerning the two neighbouring blocks is examined, *i.e.* the type of the blocks on both sides of the block boundary in question. According to the region type information the value of the parameter n may further be limited (truncated) to provide even better results for removing the blocking artefacts. The region type information is included *e.g.* in the coded information of pixels of one block wherein that information is maintained, or temporarily stored, during the decoding of the information of the block until a truncated value n_{tr} of parameter n is defined.

Table 1 shows the truncation values according to an advantageous embodiment of the present invention. Table 1 applies in a situation where the maximun value of n is 6, and, of course, different truncated values would be appropriate in situations where this maximum value is other than 6. These truncation values are used for the first and second sides of the block boundary depending on the region type of the block on the first side of the block boundary and on the region type of the block on the second side of the block boundary.

type of the Block on the First side of a boundary	type of the Block on the Second side of a boundary							
	INTRA		COPY		CODED		NOT_CODED	
INTRA	n	n	2	2	n	4	n	2
COPY	2	2	2	2	2	4	2	2
CODED	4	n	4	2	4	4	4	2
NOT_CODED	2	n	2	2	2	4	2	2

TABLE 1

Each cell of Table 1 corresponding to a particular region type combination is split into two parts. The value on the left gives the truncation value *trval* for the first side of the block boundary and the value on the right gives the truncation value *trval* for the second side of the boundary. If the value of the parameter 'n' exceeds the value given in Table 1, 'n' is truncated to the truncation value *trval* in Table 1. If, however, the value of the overall activity parameter 'n' does not exceed the value given in Table 1, the value of the parameter n (originally determined from equation (2)) is retained. In Table 1 the symbol "n" indicates that further truncation is not performed and the parameter value is retained. The truncated value n_{tr} for the parameter n can also be presented by the formula:

$$n_{tr} = \min(\text{trval}, n), \tag{3}$$

The same table can be used both for filtering across vertical block boundaries (horizontal filtering) by putting "Left"/"Right" in place of "First"/"Second" and for filtering across horizontal block boundaries (vertical filtering) by putting "Bottom"/"Up" in place of "First"/"Second", respectively. Now, the value on the left gives the truncation value for the pixels on the left/below the block boundary and the value on the right gives the truncation value for the pixels on the right/above the boundary.

To further clarify the use of Table 1, an example situation is presented in the following. In this illustrative example situation "horizontal filtering"

is performed across a vertical block boundary 30. Assuming that the value for parameter n calculated from equation 2 is *e.g.* 4, the block on the left-hand side of the block boundary 30 in question is Intra type, and the block on the right-hand side of the block boundary 30 in question is Not-coded type, Table 1 indicates that the truncation value for the left-hand side is 'n' and the truncation value for the right-hand side is 2. This means that the 4 pixels closest to the block boundary (=the calculated value of n) are selected for filtering from the left-hand side of the boundary, and 2 pixels closest to the block boundary (=the truncated value of n) are selected from the right-hand side for filtering.

Another example situation is presented in the following. In this illustrative example situation "horizontal filtering" is performed across a vertical block boundary 30. Assuming that the value for parameter n calculated from equation (2) is *e.g.* 4, blocks on both sides of the block boundary 30 in question are Copy type, Table 1 indicates that the truncation value for the left-hand side is 2 and the truncation value for the right-hand side is 2. This means that the 2 pixels closest to the block boundary (=the truncated value of n) are selected for filtering from the left-hand side of the boundary, and 2 pixels closest to the block boundary (=the truncated value of n) are selected from the right-hand side for filtering.

For bidirectionally predicted frames (B-frames), truncation of the parameter n is not applied because there is no unique block type information.

The next step in the filtering method according to the invention is to determine the values of the parameters d_l and d_r, which represent activity, or the differences of pixel values between pixels on one side of the block boundary. A preferred definition for d_r is the following:

$$
\begin{aligned}
&d_r = 6, \text{ if } |r_1 - r_j| \le \beta/j \text{ with all } j \in [1,6], \\
&\text{otherwise: } d_r = i, \text{ where i fulfils the conditions} \\
&\qquad i \in [1, n_{tr}], \\
&\qquad |r_1 - r_{i-1}| > \beta/i, \text{ and} \\
&\qquad |r_i - r_j| \le \beta/j \text{ with all } j \in [1,i].
\end{aligned}
\tag{4}
$$

Here, the auxiliary parameter $\beta = 4 \cdot \log(QP)$. The value of parameter d_l is determined similarly, except that all r's are replaced by l's and the corresponding truncated value n_{tr} for the parameter n must be used.

The number 6 appears in definition (4) because the highest possible value of n is 6 according to equation (2). If n is defined differently, but the parameters d_r and d_l are defined according to definition (4), the number 6 must be replaced by the highest possible value of n according to the new definition.

With regard to the invention, it is advantageous that the values of the parameters d_r and d_l are calculated independent of one another, because the image information contained by the frame can be different on different sides of the block boundary. The invention does not limit the definition of parameters d_r and d_l, but according to the guidelines of definition (4) it is advantageous that these parameters are used to limit the blocking artefact processing relatively close to the block boundary, if there is a real image edge near the block boundary. The essential features of definition (4) can be summarised as follows: the value of parameter d_r (and correspondingly the value of parameter d_l) provides an indication of how many pixels counted from the block boundary have approximately the same value as the pixel at the block boundary.

A high value of parameter n (e.g. 6) indicates that the difference between the pixel values at the block boundary is relatively small compared with the general variation of the pixel values within the block. In this case, it is possible that there is a real image edge near the block boundary. By selecting a sufficiently small value of parameter d_r (or d_l), it is possible to restrict the filtering aimed at correcting blocking artefacts so that it does not have a deteriorating effect on a real image edge close to the block boundary. In some situations, a large number of pixels counted from the block boundary have approximately the same value as the pixel at the block boundary. In that case, definition (4) would give the parameter d_r or (d_l) a relatively high value. However, if there is a clear discontinuity in pixel values between the blocks, the parameter n has a small value and the truncated value n_{tr} is used in the definition (4) which make sure that an unreasonably high value is not selected as the value of the parameter d_r (or d_l). Otherwise, a rela-

tively high value of the parameter d_r (or d_l) would result in unnecessary filtering.

If blocks on both sides of the block boundary are Intra-type blocks, the truncation has no effect on the selection of the parameter values n, d_r and d_l. On the other hand, if at least one of the blocks has a type other than Intra, the truncation of the value n according to the formula (3) may limit the number of pixels filtered. This has the advantage that the block boundaries are not smoothed too much.

In addition, the largest possible number of pixels to be filtered must be decided, *i.e.* filtering window. This does not have a notation of its own in Figure 2, but it can be e.g. 3, which means that filtering can only be used to correct the value of the pixels r_1, r_2, r_3, l_1, l_2 and l_3.

When the values of the parameters n, n_{tr}, d_r and d_l have been determined, filtering is carried out using a suitable filter. The invention does not limit the kind of filter that can be used, but a filtering arrangement that has been found preferable, will be described in the following. Filtering is used to determine a new value for the pixels selected for filtering. In a preferred embodiment of the invention, a new pixel value is determined for a given pixel by calculating the mean of the pixel values that appear in a filtering window.. In the preferred embodiment, the filtering window is symmetrical with regard to the pixel to be filtered and contains, in addition to the pixel to be filtered, one, two or three pixels from its both sides, depending on the values of the parameters d_r and d_l as described hereinafter. Of course these are only examples and other values could be chosen in situations where n, n_{tr}, d_r and d_l are defined differently. The calculated mean value is rounded to the closest digitized pixel value, whereby it becomes the new value of the filtered pixel.

Table 2 shows the determination of the width of the filtering window for the pixels r_1, r_2 and r_3 according to the value of parameter d_r in a preferred embodiment of the invention. The values of the pixels l_1, l_2 and l_3 are determined in the same manner according to the value of the parameter d_l. In the table, X means that the pixel in question is not filtered at all, and the number means that the filtering window includes a number of pixels shown by the number from each side of the pixel

being examined. Among other things, Table 2 shows that for filtering to be applied to any pixel, parameters d_r and d_l must both have a value greater than 1.

d_r ($d_l > 1$)	r_1	r_2	r_3
1	X	X	X
2	1	X	X
3	1	1*	X
4	2	2	X
5	2	2	2**
6	3 or 2***	3	3

* the filtered value of pixel r_1 is used for filtering of pixel r_2

** the filtered values of pixels r_1 and r_2 are used for filtering pixel r_3

*** 3 if $d_l > 2$, otherwise 2.

The above description relates to implementing the filtering on one horizontal part of a pixel row, which part is 12 pixels long and located symmetrically on both sides of a vertical block boundary. The description can be easily generalized to concern vertical parts of pixel columns, which are located symmetrically on both sides of a horizontal block boundary: Figure 2 can be turned 90 degrees counter-clockwise, whereby block boundary 30 becomes horizontal, and the pixels shown in the figure form part of the vertical pixel column so that pixels r_1 - r_6 are the pixels above and pixels l_1 - l_6 are the pixels below. To filter block boundaries throughout the whole frame by applying the method according to the invention, all vertical block boundaries of the frame are examined row by row and all its horizontal block boundaries column by column. The order has no significance at such, and thus all the horizontal block boundaries of the frame could be examined first column by column, and then all the vertical block boundaries row by row. In an advantageous embodiment of the invention the filtering is repeated line by line, *i.e.* the first line of the pixels in the blocks (besides the boundary) is filtered first, then the second line, etc.

Figure 3 shows at which points the prior art image codec can be improved by applying filtering according to the invention. The first alternative is to place the block implementing the filtering according to the invention in the output of the decoder of the receiver as illustrated by reference number 31. In this case, block boundaries in the video frame are only filtered after decoding of all blocks within the frame. This requires block type information to be stored for all the blocks in one frame. Another alternative is to place the block carrying out the filtering according to the invention in the receiver before the point at which the decoded frame is directed to the frame memory 25 for forming a prediction frame, as illustrated by reference number 32. In this case block type information for all blocks within the frame must also be stored, as block boundary filtering is still performed after decoding and reconstructing the entire frame. However, this alternative has the advantage that the removal of blocking artefacts also has an effect on the formation of a prediction frame, whereby blocking artefacts in one frame are not propagated via the prediction frame to the next frames. In order to achieve the last mentioned effect, the block performing filtering according to the invention can be placed before the frame memory 25 or after it, but the location shown by reference number 32 is preferred, because when applied at this stage, the filtering influences simultaneously the frame to be output by the receiving decoder and the frame to be saved in the memory. In the transmitter, the block carrying out filtering according to the invention can be placed as shown by reference numbers 33 and 34 before the frame memory 16 or after it, if it is desired that the invention is also applied to producing a corrected prediction frame at the transmission end.

The block carrying out the filtering according to the invention is particularly advantageously implemented in a digital signal processor or a corresponding device suited for processing a digital signal, which can be programmed to apply predetermined processing functions to the signal received as input data. At the programming stage of the digital signal processor, the definitions 35 - 39 are saved according to Figure 4 for calculating the parameters that control filtering. During operation according to Figure 5, the frame is saved temporarily in the register 41, so that it can be processed in the signal processor pixel by pixel. A number of pixels indicated by the parameter n_{ltr} are selected from the

frame as the pixels to be examined 42 at a given instant from each side of a certain point of a certain block boundary, the d-parameters 43 are calculated, filtering 44 is performed, and these measures are repeated, until all boundaries of all blocks have been filtered/processed, after which the frame can be output from the register 41 and a new frame saved for processing. The measures according to Figures 4 and 5 can be carried out in a separate signal processor or they can be part of the operation of such a general processor which also contains other arrangements for signal processing.

A storage media can be used for storing a software program comprising machine executable steps for performing the method according to the invention. Then in an advantageous embodiment of the invention the software program can be read from the storage media to a device comprising programmable means, *e.g.* a processor, for performing the method of the invention.

The invention can be modified without departing from the scope defined by the claims hereinafter, using the capabilities of a person skilled in the art without actual inventive steps. For example, the parameter Δ can be calculated using the formula $\Delta = |(r_1 + r_2) - (l_1 + l_2)|$ or some other formula regarded as suitable. The definitions of other parameters above have also been intended as examples only. A particularly advantageous use of the invention is in mobile teleconferencing applications, digital television receivers and other devices that at least receive and decode digital video image.

Figure 6 shows a mobile terminal 46 intended for use as a portable teleconferencing device and applying the deblocking filter method according to the invention. The mobile terminal 46 comprises advantageously at least display means 47 for displaying images, audio means 48 for audio information, keyboard 49 for inputting *e.g.* user commands, radio part 50 for communicating with mobile network (not shown), processing means 51 for controlling the operation of the device, memory means 52 for storing information, and preferably a camera 53 for taking images.

The present invention is not solely restricted to the above presented embodiments, but it can be modified within the scope of the appended claims.

Claims:

1. A method for removing blocking artefacts from a frame of a digital video signal, which has been coded by blocks and then decoded, the coding method for a block being selected according to a predetermined set of coding types, in which method at least one pixel (n) is selected for examination from at least one side of a block boundary (30), and a value of at least one pixel selected for examination is corrected by filtering, **characterized** in that the filtering applied on the block boundary depends on the block types of the frame in the environment of the block boundary (30).

2. A method according to Claim 1, **characterized** in that the number of pixels (n) selected for examination depends on the image content of the frame in the environment of the block boundary (30), and that the number of pixels (n) selected for examination further depends on the block types of the frame in the environment of the block boundary (30).

3. A method according to Claim 2, **characterized** in that the number of pixels selected for examination depends on the size of the quantization step of the coefficients used in the coding of the blocks.

4. A method according to Claim 3, **characterized** in that the number of pixels (n) selected for examination is determined by the formula

$$n = \begin{cases} 0 & & \Delta & \geq 2.00\alpha \\ 1 & 1.50\alpha \leq & \Delta & < 2.00\alpha \\ 2 & 1.00\alpha \leq & \Delta & < 1.50\alpha \\ 3 & 0.66\alpha \leq & \Delta & < 1.00\alpha \\ 4 & 0.40\alpha \leq & \Delta & < 0.66\alpha \\ 5 & 0.25\alpha \leq & \Delta & < 0.40\alpha \\ 6 & 0 \leq & \Delta & < 0.25\alpha \end{cases}, \qquad (2)$$

wherein $\alpha = QP \cdot \log(QP)$ and QP is the size of the quantization step of the coefficients used in the coding of the blocks.

5. A method according to Claim 2, 3, or 4, **characterized** in that the number of pixels (n) is first defined according to the image content of the frame in the environment of the block boundary (30), and the

number of pixels (n) is further truncated according to the block types of the frame in the environment of the block boundary (30).

6. A method according to Claim 5, **characterized** in that the truncated value (n_{tr}) of the number of pixels (n) is determined by selecting a truncation value (trval) according to the table

	Region type of the Block on the Second side							
Region type of the Block on the First side	INTRA		COPY		CODED		NOT_CODED	
INTRA	n	n	2	2	n	4	n	2
COPY	2	2	2	2	2	4	2	2
CODED	4	n	4	2	4	4	4	2
NOT_CODED	2	n	2	2	2	4	2	2

and using said selected truncation value (trval) with the formula

$$n_{tr} = \min(\text{trval}, n), \qquad (3).$$

7. A method according to any preceding Claim, **characterized** in that certain pixels to be filtered are selected from the pixels selected for examination, and a new value is determined for each pixel to be filtered on the basis of pixels that appear in a filtering window set around the pixel.

8. A method according to Claim 7, **characterized** in that the new value of the pixel to be filtered is the mean value of the pixels that appear in the filtering window.

9. A method according to Claim 7, **characterized** in that for determining a new value for the pixels to be filtered on the first side of the block boundary, said filtering window is used, and the size of the window is determined by the table

d_r ($d_l > 1$)	r_1	r_2	r_3
1	X	X	X
2	1	X	X
3	1	1*	X
4	2	2	X
5	2	2	2**
6	3 or 2***	3	3

where

* the filtered value of pixel r_1 is used for filtering of pixel r_2

** the filtered values of pixels r_1 and r_2 are used for filtering pixel r_3

*** 3 if $d_l > 2$, otherwise 2,

wherein an integer parameter d_r indicates activity on the first side of the block boundary, and an integer parameter d_l indicates activity on the second side of the block boundary, r_1, r_2 and r_3 are the three pixels on the first side of the block boundary closest to the boundary in this order, X means that the pixel is not filtered, the number means that in addition to the pixel to be filtered, a quantity of pixels shown by the number are taken to the filtering window from both sides of the pixel to be filtered, and "3 or 2" means "3, if $d_l > 2$, otherwise 2", and for determining the new value of the pixels to be filtered on the other side of the block boundary, a filtering window defined similarly is used, with the exception that all r's are replaced by l's and vice versa.

10. A method according to Claim 9, **characterized** in that

$d_r = 6$, if $|r_l - r_j| \leq \beta/j$ with all $j \in [1,6]$,
otherwise: $d_r = i$, where i must meet the conditions

$i \in [l, n_{tr}]$,
$|r_l - r_{l+l}| > \beta/i$, and
$|r_l - r_j| \leq \beta/j$ with all $j \in [l,i]$,

wherein the auxiliary parameter $\beta = 4 \cdot \log(QP)$ and QP is the size of the quantization step of the transformation coefficients used in transformation coding of the blocks, and the value of the parameter d_l is determined similarly, with the exception that all r's are replaced by l's.

11. A device for removing blocking artefacts from a frame of a digital video signal, which has been coded by blocks and then decoded, the coding method for a block being selected according to a predetermined set of coding types, which device comprises means for selecting at least one pixel (n) for examination from at least one side of a block boundary (30), and a filter for correcting a value of at least one pixel selected for examination, **characterized** in that the filter has been arranged to operate adaptively according to the block types of the frame in the environment of the block boundary (30).

12. A device according to Claim 11, **characterized** in that it comprises means (41) that operate adaptively according to the image content of the frame, for selecting pixels for examination and filtering, and that means (41) for selecting pixels for examination and filtering comprises further means (42) for examining block types of the frame in the environment of the block boundary (30).12. A device according to Claim 11, **characterized** in that it comprises means (42) for selecting the number of pixels for examination depending on the size of the quantization step of the coefficients used in the coding of the blocks.

13. A device according to Claim 12, **characterized** in that the means (42) for selecting the number of pixels for examination comprises means (35) for determining said number of pixels by the formula

$$n = \begin{cases} 0 & \Delta \geq 2.00\alpha \\ 1 & 1.50\alpha \leq \Delta < 2.00\alpha \\ 2 & 1.00\alpha \leq \Delta < 1.50\alpha \\ 3 & 0.66\alpha \leq \Delta < 1.00\alpha \\ 4 & 0.40\alpha \leq \Delta < 0.66\alpha \\ 5 & 0.25\alpha \leq \Delta < 0.40\alpha \\ 6 & 0 \leq \Delta < 0.25\alpha \end{cases}, \qquad (2)$$

wherein $\alpha = QP \cdot \log(QP)$ and QP is the size of the quantization step of the coefficients used in the coding of the blocks.

14. A device according to Claim 11, 12, or 13, **characterized** in that it comprises means (42) for truncating the number of pixels (n) selected for examination on the basis of said block types

15. A device according to any of the Claims 11 to 14, **characterized** in that the means (42) for selecting the number of pixels for examination comprises means for defining the number of pixels (n) according to the image content of the frame in the environment of the block boundary (30), and means for truncating the number of pixels (n) according to the block types of the frame in the environment of the block boundary (30).

16. A device according to Claim 15, **characterized** in that the means for truncating the number of pixels (n) comprises means for selecting a truncation value (trval) according to the table

Type of the Block on the First side	Type of the Block on the Second side							
	INTRA		COPY		CODED		NOT_CODED	
INTRA	n	n	2	2	n	4	n	2
COPY	2	2	2	2	2	4	2	2
CODED	4	n	4	2	4	4	4	2
NOT_CODED	2	n	2	2	2	4	2	2

and using said selected truncation value (trval) with the formula

$$n_{tr} = \min(trval, n), \qquad (3).$$

17. A device according to any of the Claims 11 to 16, **characterized** in that it comprises means (42) for selecting pixels to be filtered from the pixels selected for examination, means (42) for defining a filtering window, and means for determining a new value for each pixel to be filtered on the basis of pixels that appear in a filtering window set around the pixel.

18. A device according to Claim 17, **characterized** in that the means for determining a new value for each pixel comprises means for calculating mean values of the pixels that appear in the filtering window.

19. A device according to Claim 17, **characterized** in that the means for determining a new value for each pixel comprises means for using said filtering window for the pixels to be filtered on the first side of the

block boundary, and means for determining the size of the window by the table

d_r ($d_l > 1$)	r_1	r_2	r_3
1	X	X	X
2	1	X	X
3	1	1*	X
4	2	2	X
5	2	2	2**
6	3 or 2***	3	3

where

* the filtered value of pixel r_1 is used for filtering of pixel r_2

** the filtered values of pixels r_1 and r_2 are used for filtering pixel r_3

*** 3 if $d_l > 2$, otherwise 2,

wherein an integer parameter d_r indicates activity on the first side of the block boundary, and an integer parameter d_l indicates activity on the second side of the block boundary, r_1, r_2 and r_3 are the three pixels on the first side of the block boundary closest to the boundary in this order, X means that the pixel is not filtered, the number means that in addition to the pixel to be filtered, a quantity of pixels shown by the number are taken to the filtering window from both sides of the pixel to be filtered, and "3 or 2" means "3, if $d_l > 2$, otherwise 2", and means for using a filtering window defined similarly for determining the new value of the pixels to be filtered on the other side of the block boundary, with the exception that all r's are replaced by l's and vice versa.

20. A device according to Claim 19, **characterized** in that

$d_r = 6$, if $|r_l - r_j| \leq \beta/j$ with all $j \in [1,6]$,
otherwise: $d_r = i$, where i must meet the conditions
$l \in [1, n_{tr}]$,
$|r_l - r_{i+l}| > \beta/i$, and
$|r_l - r_j| \leq \beta/j$ with all $j \in [l,i]$,

wherein the auxiliary parameter $\beta = 4 \cdot \log(QP)$ and QP is the size of the quantization step of the transformation coefficients used in transformation coding of the blocks, and the value of the parameter d_i being determined similarly, with the exception that all r's are replaced by l's.

21. A device according to any of the Claims 11 to 20, **characterized** in that it comprises programmable means (42) for selecting pixels from the saved frame as the pixels to be examined, programmable means (45) for selecting the pixels to be filtered from among the pixels to be examined, and programmable means (44) for determining the new value of the pixels to be filtered.

22. A video encoder (10) comprising means (35—44) for coding and decoding a digital video signal by blocks, means for selecting the coding method for a block according to a predetermined set of coding types, which encoder comprises means for selecting at least one pixel (n) for examination from at least one side of a block boundary (30), and a filter for correcting the value of pixels selected for examination, **characterized** in that the filter has been arranged to operate adaptively according to the block types of the frame in the environment of the block boundary (30).

23. A video decoder (20) comprising means (35—44) for removing blocking artefacts from a frame of a digital video signal, which has been coded by blocks and then decoded, the coding method for a block being selected according to a predetermined set of coding types, which video decoder comprises means for selecting at least one pixel (n) for examination from at least one side of a block boundary (30), and a filter for correcting the value of pixels selected for examination, **characterized** in that the filter has been arranged to operate adaptively according to the block types of the frame in the environment of the block boundary (30).

24. A video codec (10, 20) comprising means (35—44) for coding and decoding a digital video signal by blocks, means for selecting the coding method for a block according to a predetermined set of coding types, means for removing blocking artefacts from a frame of a digital video signal, which video codec comprises means for selecting at least

one pixel (n) for examination from at least one side of a block boundary (30), and a filter for correcting the value of pixels selected for examination, **characterized** in that the filter has been arranged to operate adaptively according to the block types of the frame in the environment of the block boundary (30).

25. A mobile terminal (46) comprising a video codec (10, 20), which comprises means (35—44) for coding and decoding a digital video signal by blocks, means for selecting the coding method for a block according to a predetermined set of coding types, means for removing blocking artefacts from a frame of a digital video signal, which video codec comprises means for selecting at least one pixel (n) for examination from at least one side of a block boundary (30), and a filter for correcting the value of pixels selected for examination, **characterized** in that the filter has been arranged to operate adaptively according to the block types of the frame in the environment of the block boundary (30).

26. A storage media for storing a software program comprising machine executable steps for coding and decoding a digital video signal by blocks, for selecting the coding method for a block according to a predetermined set of coding types, for removing blocking artefacts from a frame of a digital video signal, for selecting at least one pixel (n) for examination from at least one side of a block boundary (30), for correcting the value of pixels selected for examination by filtering, **characterized** in that the software program further comprises machine executable steps for filtering adaptively according to the block types of the frame in the environment of the block boundary (30).

Abstract:

The invention relates to a method for removing blocking artefacts from the frame of a digital video signal, which has been coded by blocks and then decoded. The coding method for a block is selected according to a predetermined set of coding types. A certain number of pixels (n) are selected for examination from both sides of a block boundary (30). The value of the pixels selected for examination is corrected by filtering, and the number of pixels (n) selected for examination depends on the image content of the frame in the environment of the block boundary (30)., and on the block types of the frame in the environment of the block boundary (30).

Fig. 5

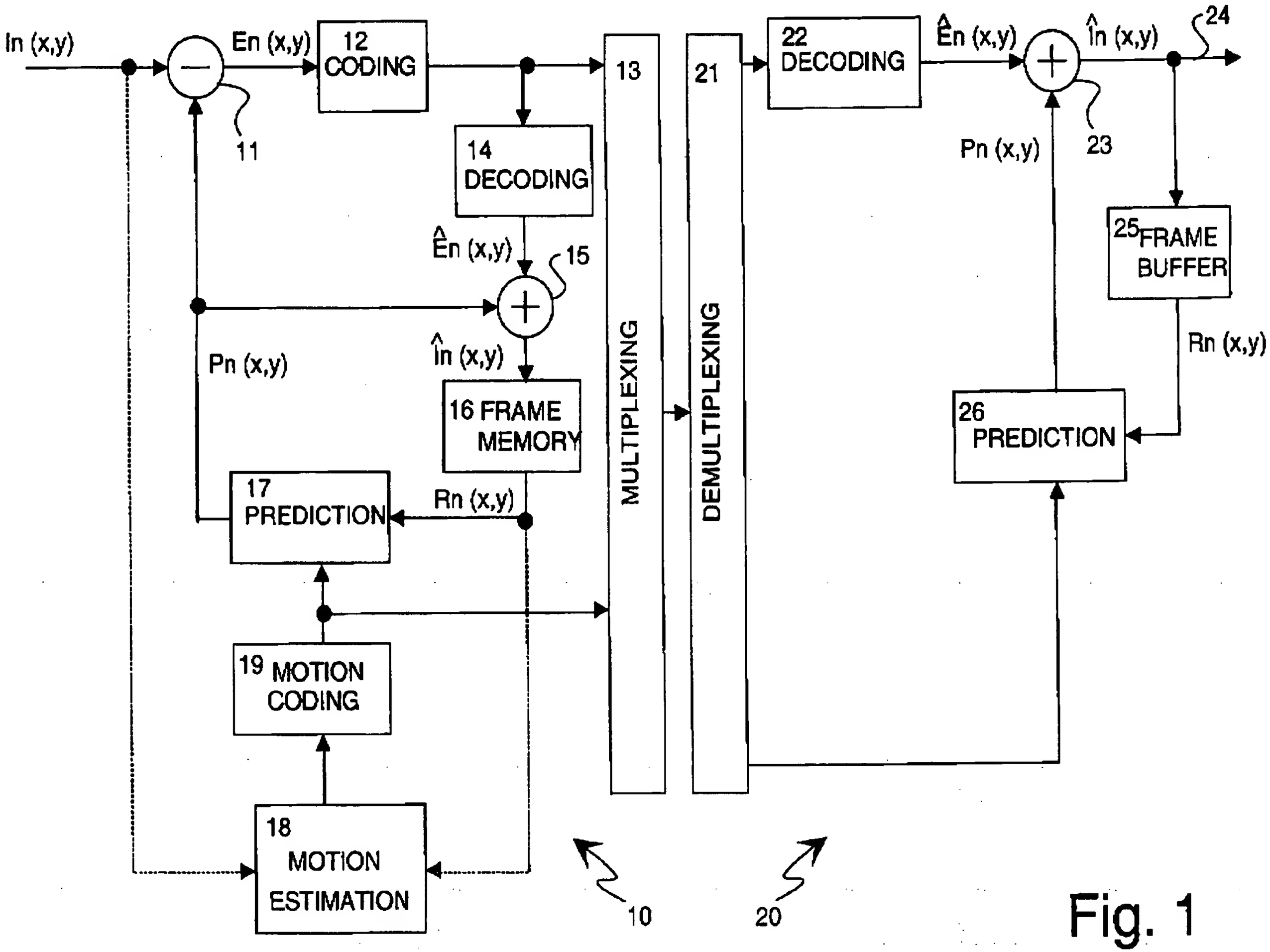

Fig. 1

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TAMPEREEN PATENT PRH
028
1/6

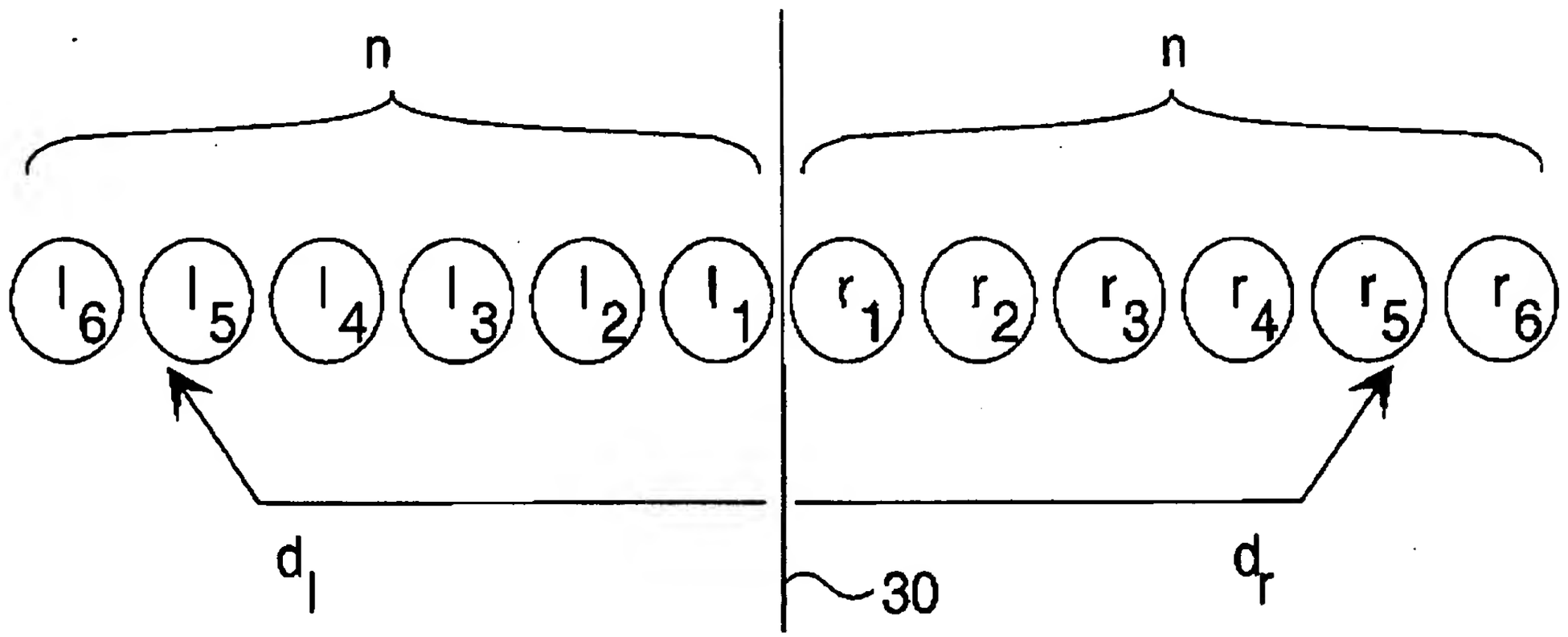

Fig. 2

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PATREK ASIAKASPALVELU; Sivu 29
PATENT + PRH
029

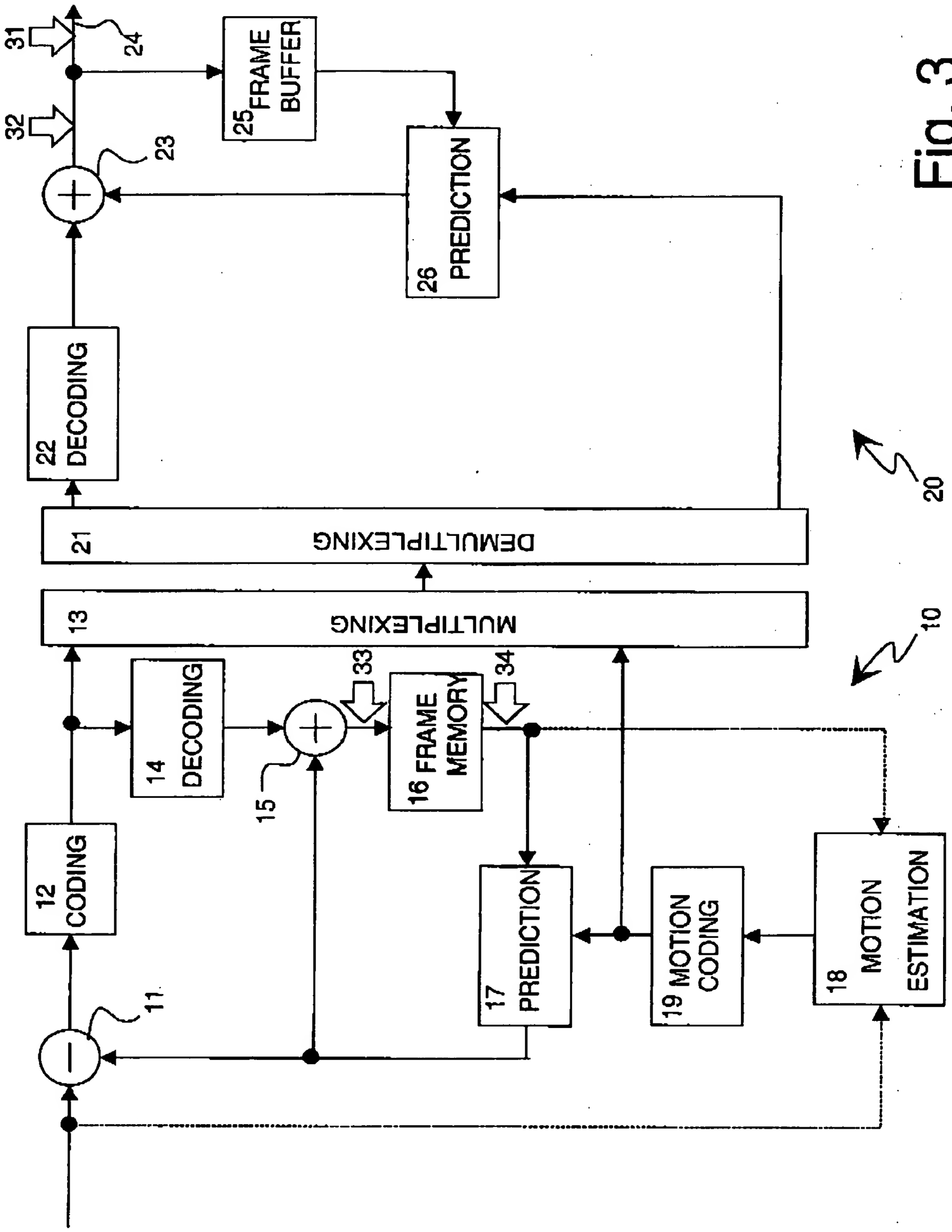
31
24
25 FRAME BUFFER
32
23
26 PREDICTION
22 DECODING
20
21 DEMULTIPLEXING
13 MULTIPLEXING
10
14 DECODING
33
34
16 FRAME MEMORY
15
12 CODING
17 PREDICTION
19 MOTION CODING
18 MOTION ESTIMATION
11

Fig. 3

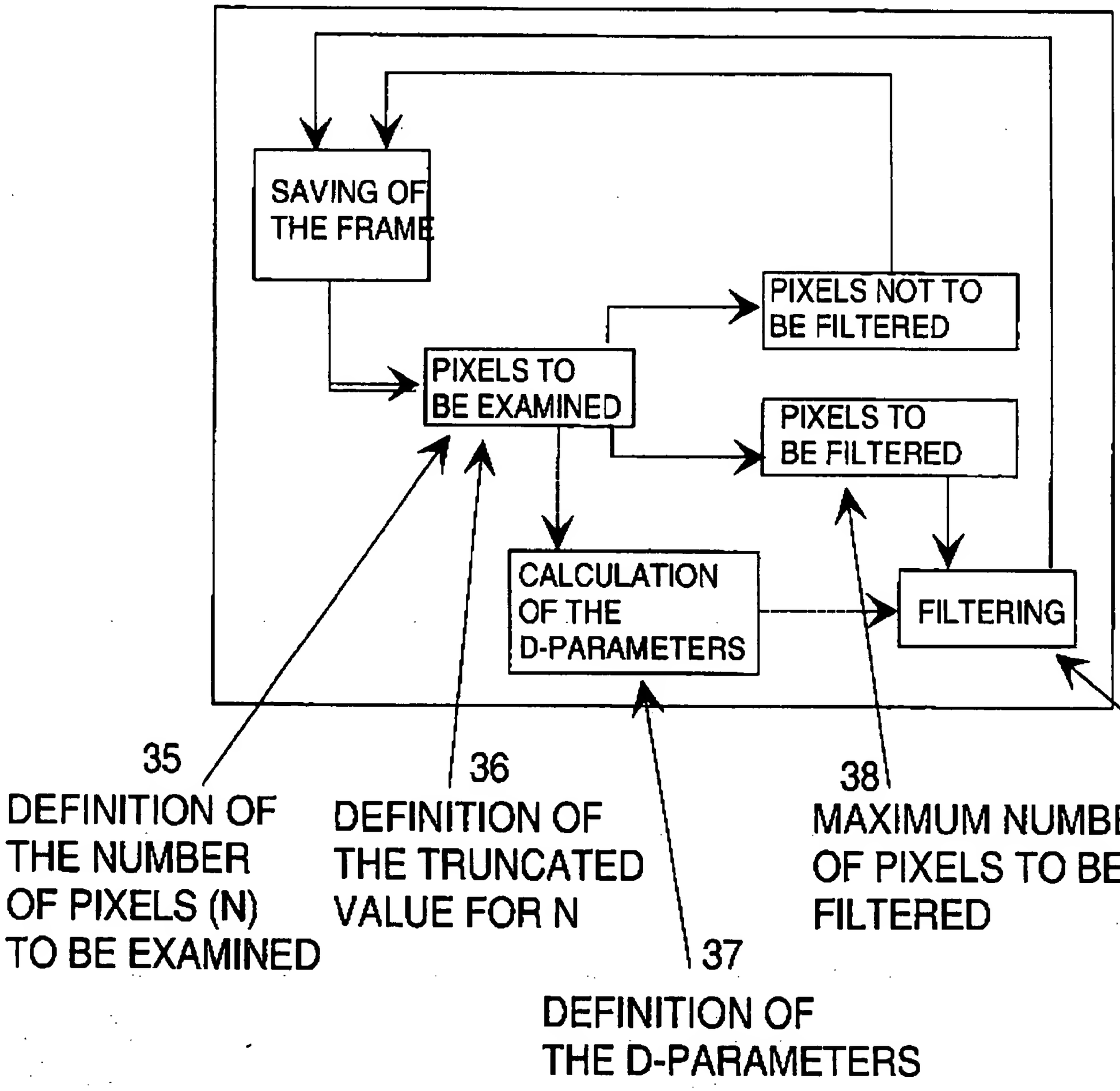

Fig. 4

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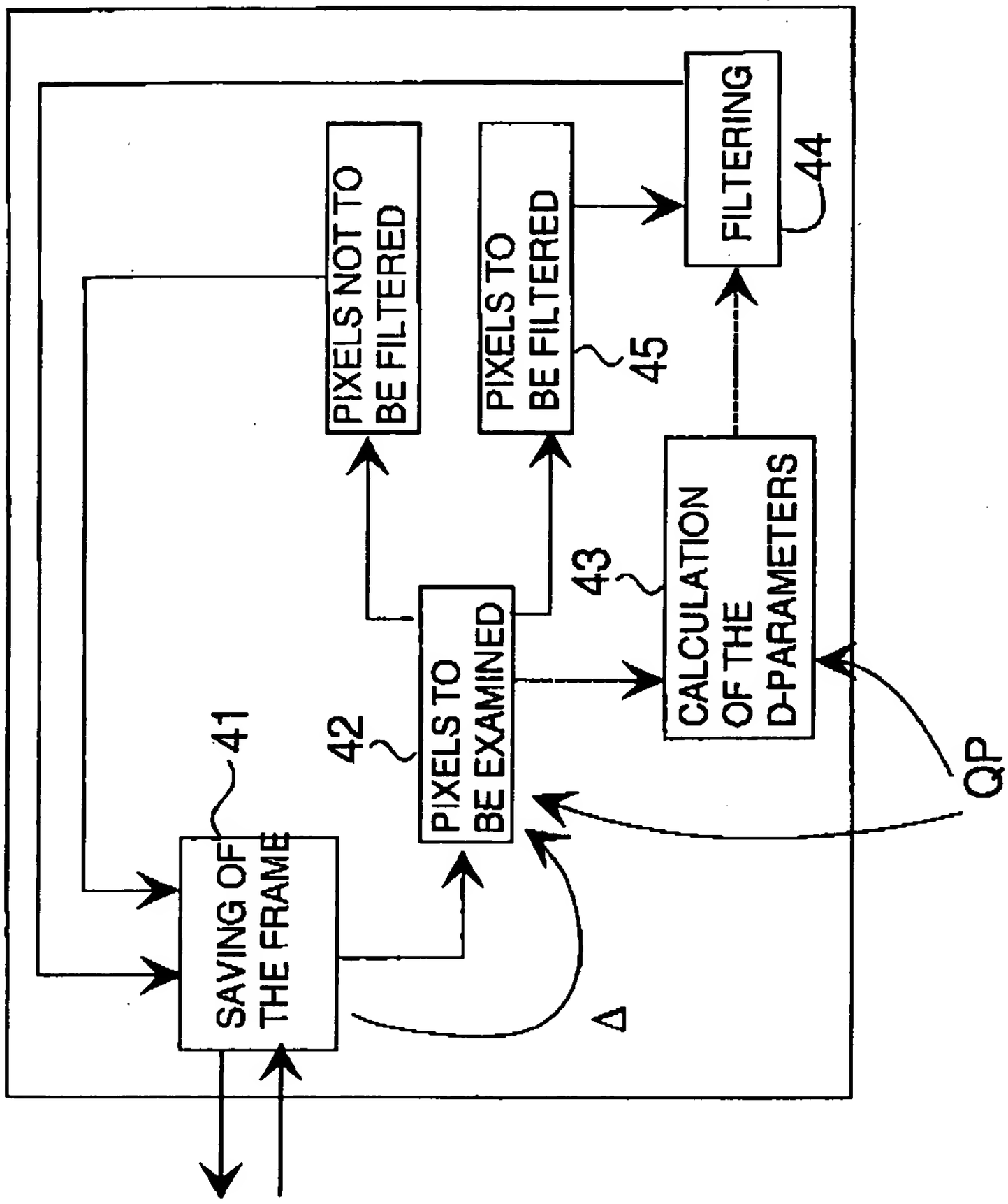
TAMPEREEN PATENT PRH
031

5

Fig. 5


SAVING OF THE FRAME
41
PIXELS TO BE EXAMINED
42
CALCULATION OF THE D-PARAMETERS
43
FILTERING
44
PIXELS NOT TO BE FILTERED
PIXELS TO BE FILTERED
45
QP

6

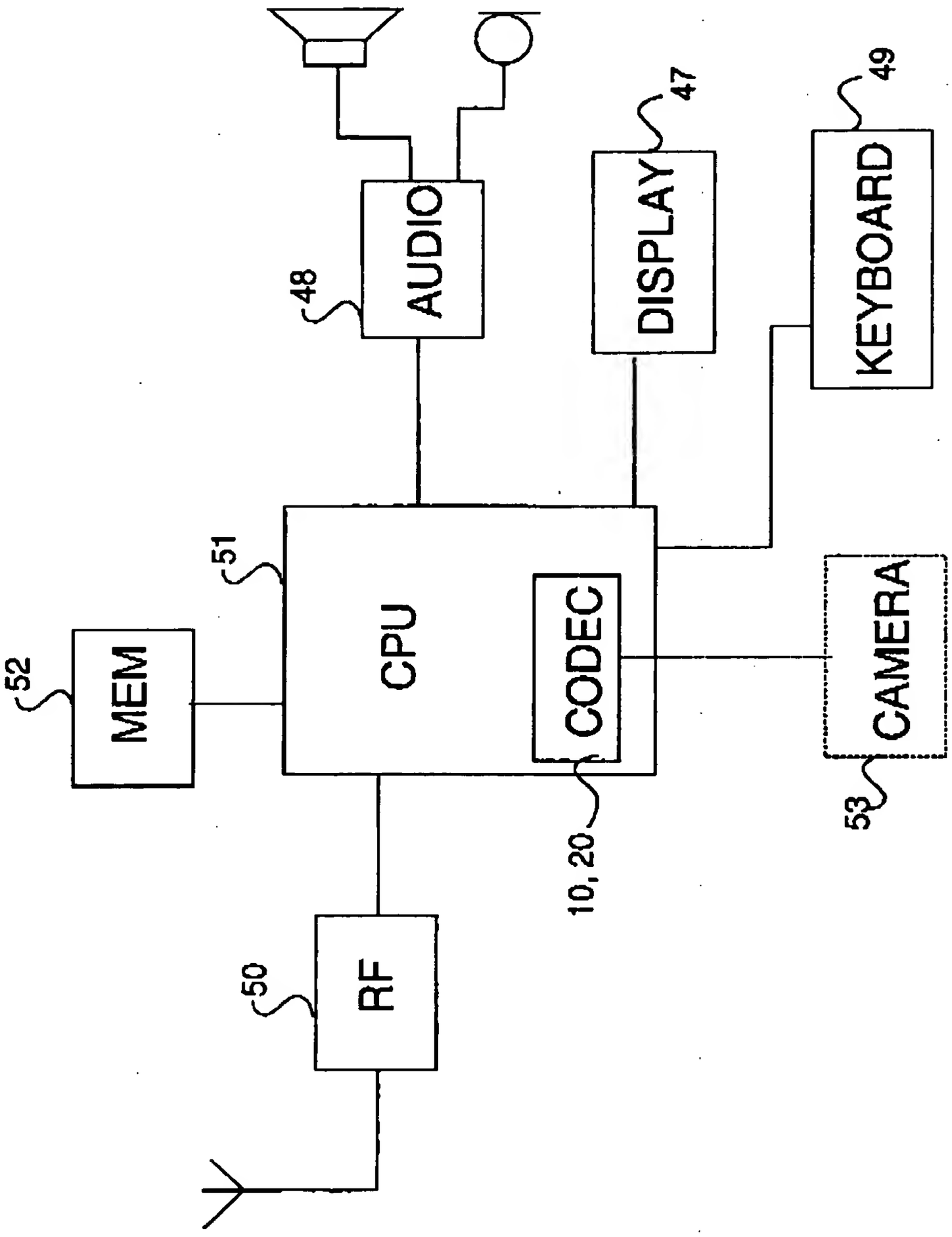

AUDIO
48
DISPLAY
47
KEYBOARD
49
CPU
51
CODEC
10, 20
MEM
52
CAMERA
53
RF
50

Fig. 6